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SUMMARY OF DEMONSTRATION METHODS FOR EXTINGUISHING CULM-BANK FIRES

R. C. Flegal, et al

Environmental Protection Agency
Research Triangle Park, North Carolina

July 1973

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R. C. Flegal
and
N. J. Gahr

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
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ABSTRACT

Sealing, grouting, and mechanical-hydraulic methods of extinguishing burning coal-refuse banks were evaluated through 15 demonstration grants in three states of the Appalachian region of the United States. The primary purpose of the demonstration grant program was to evaluate various techniques for extinguishing culm-bank fires. Both effectiveness and unit cost were major considerations in the evaluation. Mechanical-hydraulic methods were the most successful procedures used in terms of effectiveness and economy; they completely extinguished the fires and had a moderate unit cost of $0.66 to $2.19 per cubic yard of material treated. These methods, however, require large quantities of water and a large disposal area - requirements that are not always present at burning culm-bank sites. The wide diversity of coal-refuse-bank sizes, shapes, compositions, and locations makes selection of a universally recommended control method impossible.

Key words: culm-bank fires, air pollutant emissions, demonstration projects, costs.

SUMMARY AND RECOMMENDATIONS

Fifteen demonstration grants were funded by the Federal government between July 1966 and February 1968 to determine efficient, effective, and economical methods of extinguishing culm-bank fires in three states of the Appalachian region.

Three basic methods were demonstrated:

1. Sealing - the prevention of air from reaching the hot zones of the bank. The fire is extinguished because of insufficient oxygen for combustion.

2. Grouting - the injection of a slurry consisting of water, limestone, vermiculite, sodium bicarbonate, or vermiculite plus sodium bicarbonate into the hot zones of the pile.

3. Mechanical-Hydraulic - the use of water as the extinguishment medium. The quenched material is subsequently repiled and compacted.

Mechanical-hydraulic methods were the most successful procedures used in terms of effectiveness and economy; they completely extinguished the fire and had a moderate unit cost of $0.66 to $2.19 per cubic yard of material treated.

Some of the sealing methods yielded low unit costs of $0.20 to $1.04 per cubic yard, but were not successful in completely extinguishing the fires. One recent sealing project at Iselin, Pennsylvania, (appendix A.9) appears to have successfully extinguished the fire but at a relatively high unit cost of $3.36 per cubic yard.

In three of the four grouting projects, the grout was not able to completely extinguish the fires and also had high unit costs of $1.50 to $6.51 per cubic yard. In the fourth project, however, at Fails Slope, Pa., the method appears to have extinguished the fire at an acceptable unit cost of $1.25 per cubic yard.

The 15 completed projects cost a total of $2,501,313, including contributions by the states. An estimated 3,021,485 cubic yards of burning refuse was processed, for an average unit cost of $0.83 per cubic yard.

All 15 projects had some beneficial effects upon air pollutant emissions from the banks, but efforts to measure these effects were inconclusive.

Of the 15 demonstration projects, 7 were judged to have produced good results considering both the economics and the technology involved in extinguishing the burning coal-refuse banks. Successful methods used include:

1. Grouting with a lime-limestone slurry and covering the pile with limestone refuse.

2. Sealing with polyurethane foam after shaping the pile and quenching hot spots with water.

3. Quenching or sprinkling with water; earth-movers used to repile and compact the waste. Water monitors and lagoons were also used to effectively extinguish fires.

A comparison and evaluation of the 15 projects is given in Table 1.

A mechanical-hydraulic method would be the logical choice for the control of burning culm banks that are in close proximity to densely populated areas such as the northern anthracite region of Pennsylvania. Although mechanical-hydraulic methods require ample space and abundant water, they extinguish the burning banks quickly and completely and produce low, level piles of reduced volume. These compacted, extinguished sites can be developed as commercial and industrial locations.

In contrast to the urban situation, the valleys and hills of the coal-producing states are dotted with many small, burning coal-refuse banks that are usually the only source of air pollution in the immediate area. Because of the topography, access is often difficult and sufficient water is not easily available; therefore, sealing with natural cover would probably be the chosen control method in the majority of cases. Although it is neither as quick nor as complete as mechanical-hydraulic methods in extinguishing burning banks, sealing was used in some projects, and produced dramatic effects upon local air pollution - at 30 to 50 percent of the unit cost of hydraulic methods. The sealing method appears to be effective if enough cover material is applied initially and if adequate maintenance is provided to repair erosion damage that may otherwise destroy the seal.

In some instances, grouting may be employed either separately or in combination with a refuse-limestone seal. The limestone grout and seal not only completely extinguish the burning material but also effectively neutralize runoff water that might otherwise become highly acidic after percolating through the burning bank.

CONCLUSIONS AND RECOMMENDATIONS

Factors that influence selection of the method used to extinguish fires in coal-refuse banks include: size, shape, and composition of the bank; topography; availability of water; and the proximity of the bank to population centers.

The successful methods noted in Table 1 and the potential applicability of other appropriate methods should be considered and evaluated in light of specific site conditions when efforts to extinguish coal-refuse banks are undertaken in the future.

Table 1. COMPARISON OF DEMONSTRATION METHODS BY UNITS, COSTS, AND EFFECTIVENESS RATINGS

Location and project number	Federal grant, $	Total cost, $[a]	Method demonstrated	Material processed, cubic yards	Cost per cubic yard, $[a]	Rating
Manchester, Ky. Shamrock Coal Co. 66A-2001D[b]	101,850	146,504	Grout - 40% vermiculite, 40% limestone, 20% bicarbonate of soda	22,508	6.51	Poor
Heshbon, Pa. Pennsylvania Coal and Coke Mine 66A-4103D[c]	139,874	178,498	Grout - 70% vermiculite, 20% limestone, 10% bicarbonate of soda	118,755	1.50	Partial
Heshbon, Pa. Pennsylvania Coal and Coke Mine 66A-4104D[c]	34,170	45,570	Grout - "Yellow boy" sludge from neutralization of mine water	10,300	4.42	Poor
Fails Slope, Shamokin, Pa. Rossini Coal Co. 67A-4112D[c]	30,000	40,000	Grout - lime-limestone slurry. Pile covered with limestone refuse	32,000	1.25	Good
Carrolltown, Pa. Bakerton Bank of Barnes and Tucker Coal Co. 66A-4102D[c]	117,098	156,131	Polyurethane foam seal, nitrogen injection, chemical (CWS)	150,000	1.04	Partial
Tuscarora, Pa. Mary-D Bank 66A-4107D[c]	81,220	108,293	Seal - clay on sides, cement dust on top	384,673	0.28	Partial
Allen Junction, W. Va. 66A-5301D[d]	57,389	79,979	Seal - asphaltic sand-limestone, emulsion sprayed on	410,000	0.20	Partial
Tuscarora, Pa. Mary-D Bank 67A-4110D[c]	128,621	171,495	Seal - limestone refuse, pile seeded after seal is applied	384,327	0.45	Partial
Iselin, Pa. Roch and Pittsburg Bank 67A-4111D[c]	126,066	168,090	Seal - polyurethane foam after shaping pile and quenching hot spots with water	50,000	3.36	Good
Ashley, Pa. Huber Bank 66A-4101D[c]	259,125	345,500	Quench - water, repile with earth-movers	304,000	1.14	Good
Gypsy, Pa. Maryland Trojan Mine 66A-4105D[c]	96,427	128,570	Quench - water spray, 5% ammonium sulfamate on hot spots	-	-	Poor
White Station, Pa., Westmorland Coal Co. Mine 66A-4106D[c]	49,762	66,350	Water sprinkling - repile in compacted layers	100,485	0.66	Good
Scranton, Pa. Baker Bank 66A-4108D[c]	27,073	36,097	Explosive breakup of portions of bank, water quenching and removal to disposal area	16,500	2.19	Good

Table 1 (continued). COMPARISON OF DEMONSTRATION METHODS BY UNITS, COSTS, AND EFFECTIVENESS RATINGS

Location and project number	Federal grant, $	Total cost, $[a]	Method demonstrated	Material processed, cubic yards	Cost per cubic yard, $[a]	Rating
Lackawanna County, Pa. Marvin Bank 67A-4109D[c]	240,000	448,500	Water monitors - quenching and removal by earth-mover	586,666	0.76	Good
Ashley, Pa. Huber Bank 68A-4113D[e]	281,736	381,736	(1) Water monitors, lagoons - repile and compact with earth-movers	261,771	0.71	Good
			(2) Method 1 plus water monitors to spray bank, remove to disposal area and deposit in alternate layers and compact	189,500	1.04	Good
Total all projects[f]	1,764,619	2,501,313		3,021,485		

[a] Includes cost incurred by grantee agency in supervising and monitoring the project.

[b] Grantee: Kentucky Air Pollution Control Commission.

[c] Grantee: Pennsylvania Department of Mines and Mineral Industries.

[d] Grantee: West Virginia Air Pollution Control Commission.

[e] Grantee: Commonwealth Development Association of Pennsylvania.

[f] The seven projects rated "good" processed or extinguished 1,540,992 cubic yards of material at a cost of $1,486,253 or $0.96 per cubic yard.

SUMMARY OF DEMONSTRATION METHODS FOR EXTINGUISHING CULM-BANK FIRES

1. INTRODUCTION

Burning coal-refuse piles have probably been causing air pollution since coal mining started, but methods for controlling and extinguishing the fires have only been investigated during the past 50 years in both Europe and the United States. These efforts have frequently met with short-term success, but after a year or two the piles have reignited. Because air pollution was not considered a serious problem, except in local areas, these surface coal-refuse fires did not attract nationwide attention.

With the increased interest in air pollution abatement in recent years, studies of the burning-culm-bank problem have increased and several states have begun programs to extinguish culm-bank fires. Activity to expedite public works projects in many areas where mine-refuse fires cause serious air pollution problems increased within the Federal government with the passage of the Appalachian Regional Development Act of 1965. Federal grants were channeled through State agencies to fund 15 demonstration projects conducted between July 1966 and February 1968. Three basic methods were demonstrated:

1. Sealing - the covering over of the surface to prevent air from reaching the hot zones of the burning bank; the blaze is extinguished because the available oxygen is insufficient to support combustion.

2. Grouting - the injection of a slurry consisting of water, limestone, vermiculite, sodium bicarbonate, or vermiculite plus sodium bicarbonate into the hot zones of the pile.

3. Mechanical-hydraulic - the use of water to extinguish the fire and earth-moving equipment to repile and compact the quenched material.

The primary purpose of the demonstration grant program was to determine a unit cost for each effective method of extinguishing culm-bank fires.

2. DESCRIPTION OF BURNING-CULM-BANK PROBLEM

2.1 COMPOSITION OF CULM BANKS

A culm bank is an accumulation of refuse that results from mining and preparing coal for marketing. The banks are usually composed of loose rock and coal, bonded rock and coal, carbonaceous shale, and pyrites. They may also contain foreign materials such as timber, discarded machine parts, paper containers, decaying brattice cloth, oily rags, and grease. Occasionally, a culm bank may also be the dumping area for trash and garbage from nearby homes. These combustible materials, of course, substantially increase the banks' susceptibility to inadvertent or spontaneous ignition. The combustible content of culm banks can vary from 10 to 60 percent, depending on the age of the pile and the mining and preparation methods employed at the site. Prior to 1920, hand mining was the general practice, and much of it was done in relatively "clean" coal. The advent of open-pit mining, underground mechanization, and stringent market specifications required the construction of hundreds of preparation plants to "wash" the coal to remove sulfur and achieve higher levels of purity.

2.2 DIMENSIONS OF PROBLEM

Estimates from the Bureau of Mines indicate that the bituminous coal industry produces approximately 100 million tons of refuse per year.[1] Accurate estimates of the total refuse collected are difficult to obtain, however. Recent estimates from the Bureau of Mines indicate that approximately 73 billon tons of coal (anthracite and bituminous) have been mined in this country since commercial operations began. An estimated 10 percent of this total was waste and mine losses.[1,2]

In the United States, anthracite has been commercially mined since 1860 and has always required some form of cleaning, either by hand or by mechanical methods. Approximately 4.5 billion tons of anthracite coal have been mined since 1890 of which 40 percent was waste material.[3] The bituminous mines did not adopt mechanical cleaning until much later. In 1927 the Bureau of Mines reported that only 5.3 percent of the bituminous coal produced was mechanically cleaned. The use of this process has steadily increased, and at present 64 percent of all the coal produced is mechanically cleaned.[4]

2.3 LOCATION OF BURNING BANKS

A 1969 national survey and inventory of coal-mine refuse banks by the U.S. Bureau of Mines identified, by visual determination, 292 burning banks in 13 of the 26 coal-producing states.

More than 90 percent of these burning banks were found in 7 states in the Appalachian region: West Virginia had 132 ignited banks; Pennsylvania, bituminous 48 and anthracite 25; Kentucky, 27; Ohio, 6; Alabama, 6; and Maryland, 2. Of the remaining 6 states with burning coal-refuse banks, Colorado had 15 culm-bank fires; Illinois, 4; Utah, 4; Montana, 3; Oklahoma, 1; and Washington, 1.

Calculations based on pile dimensions reported in the inventory indicate that the total volume of burning materials approximated 270 million cubic yards.

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2.4 EMISSION OF AIR POLLUTANTS

Burning coal-refuse piles form sulfuric acid and emit oxides of sulfur, which are formed by the thermal decomposition and oxidation of pyritic material in the refuse:

$$\underset{\text{ferrous disulfide (pyrite)}}{FeS_2} + \underset{\text{oxygen}}{3O_2} \longrightarrow \underset{\text{ferrous sulfate}}{FeSO_4} + \underset{\text{sulfur dioxide}}{SO_2} \qquad (1)$$

$$\underset{\text{ferrous disulfide (pyrite)}}{2FeS_2} + \underset{\text{water}}{2H_2O} + \underset{\text{oxygen}}{7O_2} \longrightarrow \underset{\text{ferrous sulfate}}{2FeSO_4} + \underset{\text{sulfuric acid}}{2H_2SO_4} \qquad (2)$$

Many burning piles also emit hydrogen sulfide. Although no information exists that delineates the mechanism of hydrogen sulfide formation in burning coal-refuse piles, two possible reactions are:

1. The reaction of sulfuric acid with pyritic material in the refuse:

$$\underset{\text{sulfuric acid}}{H_2SO_4} + \underset{\text{ferrous sulfide}}{FeS} \longrightarrow \underset{\text{ferrous sulfate}}{FeSO_4} + \underset{\text{hydrogen sulfide}}{H_2S} \qquad (3)$$

2. The reaction of carbon with sulfur dioxide to form carbon disulfide in hot sections of the pile. The carbon disulfide would hydrolize to form hydrogen sulfide:

$$\underset{\text{carbon disulfide}}{CS_2} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{hydrogen sulfide}}{2H_2S} + \underset{\text{carbon dioxide}}{CO_2} \qquad (4)$$

By virtue of the heterogeneous nature of the individual piles, there are many other possible reactions in which hydrogen sulfide is likely to be formed.

Burning piles also emit other gases usually associated with coal combustion. As these gases pass through the pile, many reactions including incomplete combustion, reduction, and the thermal decomposition of pyrite occur. One manifestation of these reactions is the appearance of small rivulets of sulfur on the surface near the site of interior burning. This sulfur could be formed by the thermal breakdown of ferrous disulfide, or by the reaction of hydrogen sulfide and sulfur dioxide:

$$\underset{\text{hydrogen sulfide}}{2H_2S} + \underset{\text{sulfur dioxide}}{SO_2} \longrightarrow \underset{\text{sulfur}}{3S} + \underset{\text{water}}{2H_2O} \qquad (5)$$

The Pennsylvania Department of Health has conducted air-sampling programs in the area of burning piles and found carbon monoxide, sulfur dioxide, hydrogen sulfide, and ammonia in samples taken from the surface of the piles. Atmospheric air sampling conducted in communities located near burning banks has frequently produced evidence of sulfur dioxide concentrations exceeding 4.5 parts per million (ppm) and of hydrogen sulfide concentrations of 4.0 ppm. Gaseous emissions of these concentrations can adversely affect the property and health of the inhabitants of nearby communities. Because

some coal miners already suffer from respiratory illnesses, the adverse health effects resulting from culm-bank emissions may be accentuated within this occupational group.

2.5 HISTORICAL EFFORTS TO CONTROL BURNING

One of the earliest efforts to extinguish a burning culm bank in this country was conducted by the Philadelphia and Reading Coal and Iron Company at its St. Nicholas Colliery near Mahoney City, Pa., during 1937 and 1938. This project involved moving approximately 1,685,300 cubic yards of burning material at a cost of $532,000.[5] The techniques employed were basically the same as those used in subsequent projects: isolating the fire area and quenching the pile with water, followed by excavating the burning material and repiling the cooled material.

The literature contains many references to private efforts to extinguish or prevent culm-bank fires.[1,5-7] The first broad-scale efforts to control burning coal-refuse piles began in England during World War II. These efforts consisted primarily of water quenching to prevent the culm-bank flames from being used as navigational check-points by German bomber pilots. Unfortunately, these endeavors stopped at the end of the war, and most of the piles reignited. The British experience not only provided several valuable techniques that were employed in later studies, but also underscored the vital importance of continued vigilance to prevent reignition.

In 1957 the U.S. Bureau of Mines initiated laboratory research to determine some of the factors affecting ignition of coal-mine refuse; the methods developed in the laboratory were then field-tested from 1963 to 1965. Laboratory studies showed that particle-size distribution of the refuse has a greater effect on spontaneous-heating tendency than does the combustible, or pyritic content. The field tests demonstrated that water, applied in sufficient quantity and over an extended period of time, can control surface burning and prevent the liberation of noxious gas.

In 1963 the Pennsylvania Department of Mines and Mineral Industries awarded a contract to Bituminous Coal Research Incorporated to explore the possibility of controlling culm-bank fires by injection of finely divided material; unfortunately, the effect of this "grout" material was temporary.

The Division of Air Pollution Control of the Public Health Service (PHS) became actively involved in the problem of burning coal-mine-refuse banks in March 1961. The first project that dealt directly with culm banks was funded in 1962 as a research grant to Pennsylvania State University. This grant was designed to determine the technical and economic feasibility of recleaning culm banks to reduce the combustible content and to produce a marketable coal product. The resulting laboratory and pilot-plant work successfully demonstrated the technical capability of meeting both objectives, but the market conditions in that area of Pennsylvania at the time (1965) made a commercial application only marginally attractive.

During June 1965, the Area Redevelopment Administration (ARA) of the U.S. Commerce Department funded a short project at the Huber Bank near Ashley, Pa. The State of Pennsylvania continued this work during October 1965. Additional efforts to extinguish the burning refuse were conducted at the Huber Bank during August and September of 1967, under a cooperative grant by the Economics Development Administration (the successor to ARA) and the State of Pennsylvania. This project was notable because it conclusively demonstrated the effectiveness of the "water cannon," or "monitor," as an earth-moving-quenching device that creates no plumes of black smoke when it disturbs the pile.

With the passage of the Appalachian Regional Development Act of 1965, activity increased within the Federal government to expedite public works projects in many areas where mine-refuse fires cause serious air pollution problems. The Public Health Service assumed the authority to undertake culm-bank abatement procedures under the Clean Air Act of 1963, and Congress appropriated $975,000 for this project during fiscal year 1966 and $525,000 for more projects in fiscal year 1967.

To date, 15 projects have been funded and completed.

3. PURPOSE OF DEMONSTRATION PROGRAM AND AIR POLLUTION CONTROL OFFICE GUIDELINES FOR AWARDING GRANTS

The primary purpose of the demonstration grant program was to determine a unit cost for each effective method of extinguishing culm-bank fires. Where possible, the unit cost was to be expressed as dollars per cubic yard of material treated. Because determination of unit costs was the focus of the study, only a limited number of before-and-after air-quality measurements were attempted, and, because of the limited availability of equipment, those measurements proved inconclusive.

Visual observation was the principal method of determining the effect of efforts to extinguish the burning banks. As a secondary method of evaluation, thermowells were placed in the various piles to permit internal temperature monitoring.

Grants were given to official State agencies for projects designed to demonstrate methods for extinguishing and controlling fires in coal-mine-refuse piles. (One grant was made to a nonprofit corporation during 1968.) Federal funds provided as much as 75 percent of the total cost of a project. The contribution of the State agency could be in cash or in services provided, but the State agency was responsible for the supervision of the project and for the preparation of reports relating to the project. Participation of Air Pollution Control Office (APCO) personnel was limited to monitoring the projects, but that cost was not included in the Federal share of the project costs.

State agencies submitted proposals for projects to APCO for approval. The State agency could enter into a contract with an outside individual, agency, or firm to perform portions of the project as approved by APCO.

In reviewing project proposals, APCO considered:

1. The potential effectiveness of the proposed method, or combination of methods, in extinguishing fires and preventing reignition.

2. The probable applicability of the proposed method, or combination of methods, to fires in piles with substantially different physical and chemical characteristics or types of locations from the one in which the proposed project was conducted.

3. The possible air pollution, water pollution, and physical danger that might result from the demonstration.

4. The severity of the existing, fire-caused air pollution problem in the area where the demonstration was to be conducted.

5. The probable relative cost of the proposed method as compared with other methods, based on: (a) the level of subsequent maintenance costs, (b) the value of materials salvageable from the pile, and (c) the extent to which the method would result in, or facilitate restoration of, usable land.

Opinions and recommendations on specific project proposals were solicited from members of the Appalachian Regional Commission and other agencies that had specific interest in such projects and from qualified professionals at universities, in other Federal agencies, and in private industry.

Applications for grants were required to include the following information:

1. A general description of the proposed project including an explanation of the theory on which the method was based and, based on previous use, a report of the effectiveness, cost, and applicability of the method.

2. A description of the bank where the proposed demonstration would be conducted, including the dimensions, the physical and chemical characteristics, the status of the fire, the topography, the proximity to populated areas, and the name of the owner.

3. A detailed description of how the project would be carried out, the portion of the fire to be controlled, the personnel and equipment to be employed, the period of time to be required, and the methods to be used to measure the effectiveness of the demonstration.

4. The cost of the project, including a budget showing the distribution of costs for personnel, equipment, supplies, and other needs; the portions to be conducted by contract services; and the proposed Federal and non-Federal contributions to the project.

Grantees were required to keep appropriate records of expenditures for audit purposes. They also submitted periodic progress and expenditure reports and a comprehensive final report of the project. The cost of the final report was included in the project budget.

4. FACTORS INFLUENCING SELECTION OF CONTROL METHODS

A 1963 Bureau of Mines survey disclosed that 40 percent of the burning culm banks in the United States were within 1 mile of a town. In some sections of the anthracite region of Pennsylvania, large burning banks are within city limits. The proximity of these banks to population centers is an added constraint in the selection of the method used to extinguish the flames. In several instances, the tested methods revealed potentially dangerous side effects that would reduce their value in heavily populated areas. At one demonstration site, mist from water monitors settled on a section of an interstate highway; during winter operations, ice formed an unanticipated traffic hazard.

Successful methods of extinguishing burning banks usually require that the pile location be accessible to heavy equipment and that adequate space surround the pile to permit rehandling the extinguished material.

An ample water supply is a primary requirement of most methods for extinguishing burning culm banks. The size of the bank and the type of control method chosen usually determine the quantities of water required. With the exception of the sealing pr jects at Tuscarora, Pa., some water was used in each of the projects to cool the bank for further work, to carry grouting material, or to douse the fire.

The use of large volumes of highly acidic water usually requires additional neutralization techniques to protect pumps and pilelines against corrosion. In addition to these techniques, the Huber and Marvin projects (appendices A.14 and A.15) required the construction of storage reservoirs to collect the run-off water for reuse and to prevent stream pollution.

The wide diversity of coal-refuse-bank sizes, shapes, compositions, and locations makes selection of a universally desirable control method impossible. The ultimate selection of a method will depend upon all of the foregoing physical considerations and upon economic factors, such as cost and potential end use of the reclaimed land.

4.1 PHYSICAL REQUIREMENTS

A mechanical-hydraulic method would be the logical choice for the control of burning culm banks that are in close proximity to densely populated areas such as the northern anthracite region of Pennsylvania. Although mechanical-hydraulic methods require ample space and abundant water, they extinguish the burning banks quickly and completely and produce low, level piles of reduced volume. Furthermore, these sites can be developed as commercial and industrial locations.

In contrast to the urban situation, the valleys and hills of the coal-producing states are dotted with many small burning-coal-refuse banks that are usually the only source of air pollution in the immediate area. Because of the topography, access is often difficult and sufficient water is not easily available; therefore, sealing with natural cover would probably be the chosen control method in the majority of cases. Although sealing is neither as quick nor as complete as mechanical-hydraulic methods in extinguishing burning banks, the projects in which it was demonstrated produced dramatic effects upon

local air pollution - at 30 to 50 percent of the unit cost of mechanical-hydraulic methods. The sealing method appears to be effective if enough cover material is applied initially, and if adequate maintenance is provided to repair erosion damage that may otherwise destroy the seal.

Where natural or mine-by-product cover is not available for adequate sealing, other cover material, such as plastic foam, will have to be employed at a much higher unit cost.

In some applications, grouting by the "Fails Slope" method may also be employed either separately or in combination with a refuse-limestone seal. The limestone grout and seal not only completely extinguish the burning material but effectively neutralize run-off water that might otherwise become highly acidic after percolating through the burning bank.

4.2 ECONOMIC CONSIDERATIONS

Mechanical-hydraulic methods were most successful in completely extinguishing culm-bank fires at moderate unit costs of $0.66 to $2.19 per cubic yard of material treated.

Some of the sealing methods yielded low unit costs ranging from $0.20 to $1.04 per cubic yard of material treated, but were not successful in completely extinguishing the fires. The sealing project at Iselin, Pa. (Table 1) appears to have successfully extinguished the fire but at a relatively high unit cost of $3.36 per cubic yard of material treated.

Three of the four grouting projects were not able to completely extinguish the fires and also had high unit costs of $1.50 to $6.51 per cubic yard. The fourth project, however, at Fails Slope, Pa., appears to have extinguished the fire at an acceptable unit cost of $1.25 per cubic yard of material treated.

The 15 completed projects cost a total of $2,501,313, including contributions by the states, and processed 3,021,485 cubic yards of burning refuse for a unit cost of $0.83 per cubic yard of material treated. Seven of these projects demonstrated the capability of completely extinguishing the fires. Two of the techniques (projects 66A-4101D and 66A-4108D) had attendant side effects that would preclude their use in densely populated areas, however. Excluding the Gypsy project, the remaining seven projects extinguished 1,480,563 cubic yards of burning refuse at a total cost of $886,470 for a unit cost of $0.601 per cubic yard of material treated.

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APPENDIX.
SUMMARIES OF DEMONSTRATION PROJECTS FUNDED BY APCO 1966 TO 1968

The 15 projects described individually in this appendix are grouped according to the method used to extinguish the fires. Grouting was the primary method in projects described in appendices A.1 through A.4, sealing in appendices A.5 through A.9, and mechanical-hydraulic in A.10 through A.15.

NOTE: Mention of a specific product or company name does not constitute endorsement by the Environmental Protection Agency.

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A.1 MANCHESTER, KENTUCKY

PROJECT NUMBER: 66A-2001D.

TERM OF PROJECT: July 1, 1967 to November 18, 1968.

OBJECTIVES:

1. To determine which of four laboratory slurry mixtures would be most suitable for large-scale grouting to extinguish culm-bank fires.

2. To demonstrate that the latent heat could be removed from a burning pile and the flow of oxygen to the interior of the pile diminished, or stopped, by grouting with a mixture of vermiculite, sodium bicarbonate, and limestone; and by using the same grout mixture with a copolymer resin added to provide stability and to seal the surface.

3. To determine the effectiveness of the demonstration by comparing temperature profiles taken before, during, and after the grouting operation.

GRANTEE: The Commonwealth of Kentucky, Air Pollution Control Commission.

CONTRACTOR: Melpar, Inc., 7700 Arlington Boulevard, Falls Church, Virginia.

FUNDS ALLOCATED:

Federal funds	$101,850.00
State services	44,654.13
Total	$146,504.13

COST PER CUBIC YARD: $6.51 (22,508 cubic yards).

STATUS AT LAST INSPECTION: (Oct. 29, 1968) - The contractor's field work was completed. Visible emissions and open flames in one area showed that the piles were not effectively extinguished.

BACKGROUND: The refuse bank near Manchester, Ky., is an actively burning bank used by the Shamrock Coal Company for waste disposal. The bank was selected because it was creating an air pollution problem in the area, was of an appropriate size for the demonstration, was reasonably accessible, and was near a stream. The Federal share of the allocated funds was used to pay for the contract work performed by Melpar, Inc. The State portion of the funds was used to pay for the services of the Kentucky Air Pollution Control Commission personnel who monitored the project, performed a sulfation survey in the project area, and maintained a temperature monitoring program for 1 year after the completion of the contract work.

METHOD: A front-end loader was used to level and compact the tops of three distinct culm piles at the site; additional dirt was added in the areas where the original mantle had been disturbed. A total of 371 holes were drilled around the periphery of the piles in 4 concentric rows to depths of 20, 15, 10, and 20 feet, from outer to inner row. A 1.25-inch steel pipe was inserted in each hole to facilitate temperature monitoring and grouting. The pipes were capped to prevent the emission of gases from the piles and to help prevent chimneys from forming within the piles.

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Selection of the grouting mixture was based on extinguishment tests conducted with a small quantity of coal-refuse pile material, on freight and material costs, and on handling characteristics of the mixtures. Mixture 1 was composed by weight of vermiculite, 40 percent; sodium bicarbonate, 30 percent; and limestone dust, 30 percent. Mixture 2 was composed of shale dust, 40 percent; sodium bicarbonate, 20 percent; fly ash, 30 percent; and fine sand, 10 percent. Mixture 3 was composed of vermiculite, 20 percent, sodium bicarbonate, 20 percent; Fuller's Earth, 20 percent; Epsom salt, 10 percent; Borax, 10 percent; gypsum, 10 percent; and coal fines, 10 percent. Mixture 4 was composed of vermiculite, 20 percent; sodium bicarbonate, 20 percent; fly ash, 30 percent; shale dust, 20 percent; and limestone dust, 10 percent. Mixtures 1, 2, and 4 were fairly comparable in cost but because shale dust, which was needed in mixtures 2 and 4, was not commercially available, mixture 1 was used for the rest of the project.

Grouting and sealing began on November 22, 1967, and was completed on December 14, 1967. In the initial phase, piles I and III were grouted and piles II and III were surface sealed. The surface sealing mixture was composed by weight of 37.50 percent expanded vermiculite, 31.25 percent sodium bicarbonate, and 31.25 percent limestone dust.

A total of 597,400 pounds of chemicals was used for the internal grouting of the piles, and 33,630 pounds were used for the surface sealing.

Temperatures were monitored from July 1, 1967, to November 18, 1967. The highest temperature recorded was 1290 °F. Temperatures were monitored intermittently during the grouting period. Piles I and II were extinguished to some degree, as evidenced by a sharp decrease in temperature, but the grouting had little effect on temperature in pile III.

Starting on January 10, 1968, 1 month after sealing, the piles were monitored for 5 days a week for a period of 60 days. The temperature decreased significantly immediately after grouting; however, approximately 72 hours after the start of temperature monitoring the internal temperatures started increasing and eventually reached 1030 °F in pile I. Piles II and III stabilized at approximately 400 °F. In April 1968, pile II was grouted internally and a surface seal was applied to pile I. The west bank of pile I was regrouted to extinguish hot spots. Piles II and III were given another surface seal at that time.

The contractor's final temperature monitoring, conducted between April 24 and June 26, 1968, showed that the second grouting and sealing operation had little effect on extinguishing the fire. Spots with temperatures as high as 920 °F were measured in pile I. Temperatures in areas of pile III had increased to as high as 990 °F. The temperature of pile II remained relatively stable for the longest period after the second grouting and sealing, but temperatures in portions of this pile had started increasing and were recorded as high as 620 °F. The Kentucky Air Pollution Commission continued to monitor the condition and temperature of the project on a monthly basis and to conduct the sulfation survey of the area until June 1969.

COMMENT AND EVALUATION: The project was not successful in extinguishing the burning culm bank at Manchester, Kentucky, and unit extinguishment cost appears excessively high. The approach used in this demonstration proved satisfactory under ideal, controlled conditions; however, culm banks rarely exist under ideal conditions. The project may have been more successful had the demonstration area been isolated from the working bank, which was also burning.

A.2 HESHBON, PENNSYLVANIA

PROJECT NUMBER: 66A-4103D.

TERM OF PROJECT: July 1, 1966 to September 30, 1968.

OBJECTIVES:

1. To investigate the technical feasibility of extinguishing coal-refuse-bank fires by grouting the fire area with a mixture of vermiculite, sodium bicarbonate, limestone dust, and resin.

2. To prevent rekindling of the fire by covering the extinguished bank with a premixed slurry of the grout.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Melpar, Inc., Falls Church, Virginia.

FUNDS ALLOCATED:

Federal funds	$133,873.80
State services	10,500.00
State funds	34,124.60
Total	$178,498.40

COST PER CUBIC YARD: $1.50 (118,755 cubic yards).

STATUS AT LAST INSPECTION: (July 1969) - Steam was emanating from surface cracks on pile I. Pile II appeared dormant. The surface covering had entirely washed off the sides of both piles.

BACKGROUND: The Heshbon bank, owned by the Pennsylvania Coal and Coke Company, is located less than 1 mile from the town of Heshbon, Pa. The bank is about 1,000 feet long and is divided into 3 piles by 2 run-off gullies; only two of the piles, containing 79,170 cubic yards and 39,585 cubic yards of material, respectively, were used for the project. The site was selected by Melpar and the Pennsylvania Department of Mines and Mineral Industries.

METHOD: After the top surfaces of the piles were leveled, four concentric rows of 3-inch-diameter holes were drilled around the top edge of each pile to depths of 20, 15, 10, and 20 feet from outermost to innermost row. Steel pipes, 1.25 inches in inside diameter and beveled at the bottom to aid the flow of grout, were inserted to maintain the openings. Each hole in the first row and every fifth hole in the fourth row were used only for temperature monitoring and were 25 feet apart. A total of 384 holes were placed in the piles.

Approximately 670,000 pounds of grout that consisted by weight of 70 percent unexpanded vermiculite, 20 percent sodium bicarbonate, and 10 percent limestone dust was mixed with 140 gallons of water and pumped into the pipes at a rate of 25 gallons per minute (gal/min) at 130 psig.

The reasons for including particular ingredients in the grout mixture were:

1. Water to serve as a vehicle for the suspension and transport of the solid components and to participate in extinguishing the fires by dissipating much of the heat.

2. Sodium bicarbonate to decompose in the heat of the fire and produce carbon dioxide.

3. Powdered limestone to inhibit air flow by filling the void spaces in the pile and to neutralize any acid water that might form during the grouting operation.

4. Unexpanded vermiculite to supplement the limestone as a filler and, by expansion on exposure to heat, to more completely fill the void spaces and further impede the flow of air to the fire.

The external covering mixture consisted of 60 pounds of expanded vermiculite, 100 pounds of unexpanded vermiculite, 40 pounds of limestone dust, and 3.75 pounds of copolymer resin in water. A total of 197,000 pounds of the mixture was applied to the pile in April and June of 1968.

Temperature measurements were taken before grouting, immediately after grouting, and after the surface covering was applied.

COMMENT AND EVALUATION: Although this pile was not entirely extinguished, visual and gaseous emissions have been greatly reduced. The temperature measurements taken monthly from August 1968 to March 1969 indicated a slight increase near one thermoprobe (386 °F in March 1969); several other spots in the pile were near the 200 °F level.

The surface covering used did not resist weathering as well as anticipated and will not be repeated on future projects.

The budget for this project contained a relatively large expenditure for "engineering, monitoring, and temperature measurements." This $10,000 expenditure added to the contractor's cost for drilling and grouting results in a cost of $57,130 for the grouting phase. The cost per cubic yard of material treated for this project was $0.48.

A.3 HESHBON, PENNSYLVANIA

PROJECT NUMBER: 66A-4104D.

TERM OF PROJECT: July 1, 1966 to November 1, 1968.

OBJECTIVES:

1. To demonstrate the effectiveness of the neutralization product of acidic mine water (yellow boy) as a grout and covering material to extinguish burning coal-refuse piles.

2. To build and demonstrate a small acid-mine-water neutralization facility.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Melpar, Inc., Falls Church, Virginia.

FUNDS ALLOCATED:

Federal funds	$34,177.50
State funds	8,392.50
State services	3,000.00
Total	$45,570.00

COST PER CUBIC YARD: $4.42 (10,300 cubic yards).

STATUS AT LAST INSPECTION: (Dec. 31, 1970) - Project was not successful. Contractors were unable to carry out project to full extent. The State planned additional work in Spring 1971.

BACKGROUND: The pile is adjacent to the larger refuse piles at Heshbon, Pa., that are described in project 66A-4103D. The bank was chosen because of its small size and its proximity to a stream of highly acidic mine water.

The neutralization of acidic mine water with lime or limestone produces a complex precipitate of calcium sulfate and hydrated ferric oxide. This material, known colloquially as yellow boy, is collected in basins that must be dredged periodically to maintain sufficient room for further neutralization. An estimated 60 to 80 tons of yellow boy are produced by the neutralization of 1 million gallons of acidic mine water. Disposal of the material without polluting the streams has become a problem in western Pennsylvania.

METHOD: After the top surface of the pile was leveled, four rows of 3-inch-diameter holes, 5 feet apart, were drilled in the north perimeter of the pile. Pipes, 1.25 inches in interior diameter and beveled at the bottom to aid the flow of grout, were inserted into the holes. The outermost row of holes, drilled as close as possible to the top edge, was 20 feet deep, the third row 15 feet deep, the second row 10 feet, and the first (innermost) row 20 feet. In all but the first row, holes were placed at 5-foot intervals. Each hole in the first row and every fifth hole in the fourth row were used for thermometry; thus, the temperature monitoring holes were 25 feet apart.

A small neutralization facility was constructed near a small stream of highly acidic mine water. Yellow boy production began in July 1968. The pile was grouted in August and the cover was applied during September 1968.

COMMENT AND EVALUATION: This project was not successful because slow production of the neutralization product limited the grout slurry to only 4 to 5 percent solids. In addition, the area of the pile that was grouted was not hot enough to solidify the grout. Grout should be at least 15 percent solids and the internal pile temperature at least 1000 °F.

The prototype neutralization facility, however, worked well with lime and limestone addition and could serve as a model that could be built by the states on other streams in the coal regions. The contractor has also done preliminary work on a mobile neutralizer that could be easily moved about on a stream or watershed.

The cost of the neutralization represented a major portion of this project ($21,595). The cost of the grouting and monitoring was approximately $23,875. If the $3,000 for state services is excluded, the cost of treating the pile was approximately $20,875, a unit cost of $2.03 per cubic yard.

Because of the relatively high unit cost compared with other methods, this method will probably not be used unless the cost of disposing of yellow boy becomes high enough to offset part of the grouting cost.

A.4 SHAMOKIN, PENNSYLVANIA

PROJECT NUMBER: 67A-4112D.

TERM OF PROJECT: August 1, 1967 to September 30, 1969.

OBJECTIVES:

1. To determine the effectiveness of a limestone-water-slurry grout for extinguishing fires on and within a coal-refuse bank.

2. To keep accurate records in order to develop unit costs for the various operations.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Drew Development Co., RD #2, Box 796, Pottsville, Pennsylvania.

FUNDS ALLOCATED:

Federal funds	$30,000
State funds	5,922
State services	4,078
Total	$40,000

COST PER CUBIC YARD: $1.25.

STATUS AT LAST INSPECTION: (Dec. 31, 1970) - Project was completely successful.

BACKGROUND: The bank, known as the Fails Slope Pile, is on the property of the Rossini Coal Company in Carbon Township, Pa. No fresh refuse has been added since the fire was discovered. The bank has been the source of noxious fumes since the onset of active burning.

METHOD: All vegetation was removed from the base of the pile to isolate the test area from other coal refuse in the vicinity. The top of the pile was graded to a concave surface and flooded with water. Grouting operations began after the surface had cooled and dried enough to permit equipment to operate. A modified hydroseeder was used to mix the water-limestone slurry. Best results were obtained with a mixture of 4 pounds of limestone per gallon of water at an injection pressure of 50 psi. Injection pipes, 1 inch in diameter, were cut into 4-foot lengths, threaded on both ends for coupling with standard ferrule and driven to the bottom of the bank by a backhoe.

A rivet head completely sealed the end of the pipe to prevent intrusion by bank material. After reaching bottom, the pipe was withdrawn a few inches to permit the loose rivet to drop out and provide an open end for injection. Injection proceeded to refusal; the pipe was withdrawn; a 4-foot section was removed; and injection resumed. This procedure was followed on each injection well from the bottom of the well to the surface of the bank.

During the project, 392 injection holes were grouted with 947 tons of pulverized limestone mixed with approximately 474,000 gallons of water. An additional 510,000 gallons of water was used to suppress fires on the surface of the bank during the flooding operation and injection period.

COMMENT AND EVALUATION: Final data that would permit complete evaluation of this project are not available. Ultimate extinguishment seems possible because (1) the entire pile was grouted, not just the periphery as in projects 66A-2001D, and (2) by withdrawing the probes in 4-foot sections, the greater part of the pile was grouted, not just the volumes adjacent to the ends of the pipes.

The cost for this project was the lowest of the grouting methods. Less the State monitoring charges, the cost per cubic yard was approximately $1.12. Competitive bidding on future projects could reduce unit costs to approximately $1.00 per cubic yard.

It is unlikely that many of the older, smaller, burning banks will lend themselves to this method because the older banks frequently contain clinkers and fused culm, which require drilling and do not allow the grout pipes to be driven by a backhoe.

A.5 CARROLLTOWN, PENNSYLVANIA

PROJECT NUMBER: 66A-4102D.

TERM OF PROJECT: June 1, 1966 to September 30, 1967.

OBJECTIVE:

To demonstrate the feasibility of bringing a burning culm bank under control with a three-phase combination of grouting and sealing techniques:

Phase 1. Injection of chemicals to extinguish and/or prevent the spread of active combustion in the pile.

Phase 2. Injection of a nitrogen-gas-purge flow into the pile to displace air and extinguish the fire.

Phase 3. Application of plastic foam to the surface of the pile to seal out air and stop combustion in coordination with phase 2.

GRANTEE: Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Callery Chemical Company, Callery, Pa.

FUNDS ALLOCATED:

Federal funds	$117,098.25
State funds	24,532.75
State services	14,490.00
Total	$156,131.00

COST PER CUBIC YARD: $1.04 (150,000 cubic yards).

STATUS AT LAST INSPECTION: (December 21, 1970) - Various hot spots broke out because of voids in the foam seal. A contract issued to repair the voids was successful.

BACKGROUND: The bank, owned by the Barnes and Tucker Coal Company, is located in West Carrolltownship, Cambria County, Pa. The pile contained approximately 150,000 cubic yards of burning refuse and was estimated to be 500 feet long, 300 feet wide, and 65 feet high at its highest point. The pile is situated at the head of a small, steep valley about 0.3-mile above the village of Bakerton; gaseous emissions, which tend to follow the valley slope downhill to the village, cause numerous complaints.

METHODS: The site was prepared by constructing an earth pond to collect mine water and a loamy-clay-filled trench to serve as a fire-stop. An estimated 4.1 million gallons of quenching water was applied during 24 days of continuous sprinkling and lancing. During the final days of the watering, and for 1 month afterwards, the bank was terraced and benched, and 57 thermowells were installed.

Air pollution testing equipment was installed at the beginning of phase 1, which began one month after watering had been stopped. During the 8-day period, two test areas were injected with CWS (proprietary chemical): the same two areas were covered with polyurethane foam 10 and 16 days later, respectively. Phase 2 began 1 month after the phase 1 holes had been covered. An estimated 5,450 cubic yards of pile material was injected with nitrogen and purged in 1 month. At the same time, the polyurethane foam covering was applied over an estimated 14,700 square yards of the pile leaving the top of the pile open to allow gases to escape. Five months later, damaged foam had to be removed; the area was then requenched and foam was reapplied.

COMMENT AND EVALUATION: The results of the first two phases, chemical treatment of hot spots and the nitrogen purge, were inconclusive but did not warrent further study. The use of polyurethane foam (phase 3), however, was demonstrated as a conditionally effective method for sealing burning refuse banks: most of the bank is still sealed in testimony to this fact.

The foam-seal method can find its major field of application in areas where water is scarce and the terrain is difficult: qualifications that apply to many small banks in Pennsylvania.

Although none of the objectives of the Carrolltown project were successfully demonstrated, this project pointed up the importance of thorough pile preparation and induced the contractor to adopt a low-profile pile for his next project rather than continue with the terraced configuration. A secondary finding was the limited value of shallow, widely spaced thermowells for monitoring hot spots in piles greater than 40 feet in depth. The burn-off of a large portion of the foam at one end of the pile demonstrated that a substantial hot zone remained deep within the pile, but none of the thermowells indicated this heat. Probes driven horizontally into the pile from the terrace, however, indicated temperatures over 752 F at depths of 1 to 2 feet below the surface. This phenomena suggests that thermowells have limited value unless they are spaced at less than 10-foot intervals and at depths of at least 20 feet. It is doubtful that piles 200,000 cubic yards or larger can be monitored effectively with thermowells alone. Temperature monitoring would also appear to be quite difficult on piles that are more than 40 feet deep. Not only would it require expensive drilling to make adequate holes for the thermowells, but the additional chimneys created by the drilling would frustrate the purpose of a sealing program. Data on the temperature history after sealing are not available.

Air-quality measurements are not complete primarily because the equipment was not on the site early enough to record background levels. Sulfur dioxide levels were reduced after the pile was sealed; average hydrogen sulfide concentrations stayed about the same, but the occurrence and magnitude of short-term hydrogen sulfide concentrations increased. In the absence of background readings, the significance of these single point readings is open to question.

The polyurethane foam sealing method yields a unit cost of $1.04 per cubic yard based on an estimated total cost of $72,162 to extinguish 150,000 cubic yards of material. The foam seal method could prove valuable in sealing banks at a relatively modest cost.

A.6 TUSCARORA, PENNSYLVANIA

PROJECT NUMBER: 66A-4107D.

TERM OF PROJECT: August 1, 1966 to July 31, 1967.

OBJECTIVES:

1. To determine whether the application of fine cement-industry waste would provide skin-deep protection against wind erosion and emission of fumes after the surface of a culm-bank had been water stabilized.

2. To determine if the underlying dust would retain its semifluid, self-sealing characteristics and contribute to the extinguishment of the fire over a period of time.

3. To determine the economy of the waste-cement-dust method.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Drew Development Company, Pottsville, Pa.

FUNDS ALLOCATED:

Federal funds	$ 81,220.00
State funds	16,573.45
State services	10,500.00
Total	$108,293.45

COST PER CUBIC YARD: $0.28 (384,673 cubic yards).

STATUS AT LAST INSPECTION: (April 24, 1969) - The major portion of the pile was adequately covered with cement dust. A small hot area appeared to be forming near the rim at the north edge of the pile. The seeding had taken root on about 30 percent of the pile. The cement-dust seal on the top of the pile was intact and grass was beginning to grow. (December 31, 1970) - Project proved completely successful.

BACKGROUND: The Mary-D Colliery Bank is located on the valley floor less than 0.25-mile from the village of Mary-D. The town of Tuscarora, for which the bank constituted a serious air pollution problem, is located 0.5-mile from the bank.

The pile estimated to contain 796,000 cubic yards of material is approximately 1,600 feet long, 1,000 feet wide and varies between 40 and 60 feet in depth. The portion treated during this project contained 384,673 cubic yards of material; the balance was treated under project 67A-4110D.

METHOD: The eastern portion of the bank was graded and shaped by bulldozers, and two banks were separated by an 8- to 12-foot wide trench, which was backfilled with incombustible sandy loam. Because the gradients were too steep to permit covering with cement dust, the northern and southern slopes were covered with sandy loam to depths of between 3 and 8 feet. A heavy rim of loam was constructed around the circumference of the bank to provide a retainer for the cement dust. A 12-inch layer of cement dust was

spread using a bulldozer supplemented by hand labor for fine grading and sprayed with water. A total of 183,600 cubic feet of cement dust was applied to the top of the bank.

COMMENT AND EVALUATION: The low cost of this method is perhaps its greatest attraction. The easy accessibility of side-covering material was the major factor in this project's low unit cost. Several other burning banks in the southern anthracite field could be treated in a similar manner.

The mantle of sandy loam and the cement dust proved to be an efficient filter for the gaseous emissions at the site. Unless one stands directly over a hot spot, it is difficult to detect any odor, and there are no visible emissions.

On April 24, 1969, there had been some erosion on the north face of the bank and a hot-spot had developed near the rim at the center of the bank. This hot-spot probably existed in 1968, but became more active because of the increased air permitted to enter the pile by erosion gullies.

A.7 ALLEN JUNCTION, WEST VIRGINIA

PROJECT NUMBER: 66A-5301D.

TERM OF PROJECT: July 1, 1966 to December 31, 1968.

OBJECTIVES:

1. To demonstrate whether the sides of a refuse bank could be effectively sealed using a spray-on, self-curing asphaltic emulsion. Fillers consisting of inert material such as fly-ash, crushed native shale, asbestos, or similar material were to be tested for their effectiveness.

2. To determine the effectiveness of the seal and the degree of cooling in the pile by continuous temperature measurement.

GRANTEE: West Virginia Air Pollution Control Commission, Charleston, West Virginia.

MAJOR CONTRACTOR: West Virginia Air Pollution Control Commission.

FUNDS ALLOCATED:

Federal funds	$57,389.22
State funds	5,200.00
State services	17,390.00
Total	$79,979.22

COST PER CUBIC YARD: $0.20.

STATUS AT LAST INSPECTION: (October 31, 1968) - Although the fire was not completely extinguished it was under control and emissions had been reduced.

BACKGROUND: The use of heavy construction equipment for the abatement of emissions from burning coal-refuse banks can be hazardous to both equipment and personnel. In addition, water supplies are frequently meager in the immediate area around many burning coal banks. The State of West Virginia, therefore, proposed to develop and test a low-cost method for sealing burning banks that involved minimal use of heavy equipment and water.

A coal-refuse pile covering approximately 8 acres near Allen Junction, W. Va., was selected for this project. The pile, owned by the Amigo Smokeless Coal Company, contained approximately 410,000 cubic yards of material. At the beginning of the project, all sides were burning.

METHOD: The top of the pile was leveled by a bulldozer. Fresh fine-coal refuse was spread on the top of the pile and over part of one side where erosion gullies had formed. The level areas were then compacted with a six-tire highway roller.

Spraying operations were conducted in December 1966, from August to December 1967, and from July to October 1968. The equipment used consisted of a commercial "Refract All" rig with a wet-mix gun, a 125-ft^3/min portable air compressor and a gaso-

line-driven water pump rated at 49 gal/min at 80 psi. Three different sealant mixtures were used. The cover mixture was composed by weight of 49 percent sand, 14 percent fly ash, 3 percent asbestos cement, 24 percent emulsion asphalt, and 10 percent water. The asbestos mixture was composed by weight of 9 percent fly ash, 21 percent asbestos cement, and 70 percent water. The filler mixture was composed by weight of 63 percent fly ash, 12 percent emulsion asphalt, and 25 percent water.

The asbestos and filler mixtures were applied to the burning coal refuse pile first in order to insulate the cover mixture from the fire and heat. The asbestos mixture was used over the hotter areas of the pile.

COMMENT AND EVALUATION: The water-emulsified asphalt base sealer was only partially successful in extinguishing the fire. Temperatures were significantly reduced at many points, but the continuous settling of the pile cracked the seals, despite several applications. Observations made since the completion of spraying operations indicated that several hot zones existed within the pile and probably would not cool without the application of more sealant and/or redressing the pile in the immediate area of the hot spots.

The unit cost of $0.20 per cubic yard is 28 percent lower than the $0.28 per cubic yard developed at Tuscarora, Pa. (project 66A-4107D). Although the projects are not directly comparable, they both involved sealing the exterior of the pile to cut off the oxygen supply to the burning zones in the interior of the bank. In the case of Tuscarora, the top of the bank was also covered.

Many burning banks in West Virginia could be controlled using a water emulsion of asphalt, fly ash, or sand as a sealant if sufficient preparation work is done on the piles before the sealant is applied. The Iselin, Pa., project (67A-4112D) demonstrated the importance of thorough preparation of the surface of the pile.

The relatively low cost of this method will undoubtedly appeal to mine operators as a preventive measure against possible fires in their active refuse piles. The method would abort or postpone active burning until more comprehensive control measures could be undertaken.

A.8 TUSCARORA, PENNSYLVANIA

PROJECT NUMBER: 67A-4110D.

TERM OF PROJECT: July 1, 1967 to September 30, 1968.

OBJECTIVE:

To determine whether the application of fine limestone (quarry screening) to a burning culm pile would provide skin-deep protection against wind and water erosion and smother the burning portions of the fire.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Drew Development Company, Pottsville, Pennsylvania.

FUNDS ALLOCATED:

Federal funds	$128,621.25
State funds	34,373.75
State services	8,500.00
Total	$171,495.00

COST PER CUBIC YARD: $0.45 (384,327 cubic yards).

STATUS AT LAST INSPECTION: (December 31, 1970) - Bank was sealed and successfully planted with grass.

BACKGROUND: The Mary-D Colliery Bank, located on the valley floor less than 0.25-mile from the village of Mary-D, Pa., constituted a serious air pollution problem for Tuscarora, Pa. The pile containing approximately 769,000 cubic yards of material is approximately 1,600 feet long, 1,000 feet wide, and varies between 40 and 60 feet in depth. The western portion of the bank, which was treated during this project, contains 384,327 cubic yards: the balance of the bank was treated under project 66A-4107D.

METHOD: The western portion of the bank was graded and shaped by bulldozers, and the southern side and part of the western end were covered with sandy loam from an adjacent strip bank. Quarry screening was hauled to the project site by truck and was pushed to the edge of the pile by bulldozer. Final grading on the sides of the pile was done by hand. The mantle is approximately 2- to 3-feet deep on the sides and 1.5- to 3.0-feet deep on the top of the pile. Extra covering was placed over and near known hot spots. Several tons of limestone quarry screening were used to cover the pile. When final grading was completed, the entire project area was hydroseeded.

COMMENT AND EVALUATION: The major portion of this pile appears to be dormant, but, in the absence of temperature probes, it is impossible to determine whether this is actually the case. The cooling process may take several years, but, if the areas of erosion are promptly repaired, hot spots in the pile will eventually go out. The mantle of limestone quarry screenings has proved to be an effective filter for the gaseous emissions: odors are only detected when standing directly over a hot spot. Surprisingly,

this odor is not hydrogen sulfide or sulfur dioxide as might be expected, but a combination of phenol and ammonia.

The unit cost of this method is moderately low compared with other methods of extinguishing culm-bank fires. Because limestone quarries are widely distributed in Pennsylvania and other states that have many coal-refuse piles, the technique will probably be widely used.

A.9 ISELIN, PENNSYLVANIA

PROJECT NUMBER: 67A-4111D.

TERM OF PROJECT: July 1, 1967 to September 30, 1969.

OBJECTIVE:

1. To study and compare various seal systems and procedures for extinguishing culm-bank fires.

2. To grade and shape the pile into a low profile.

3. To evaluate the effectiveness of surface stabilization and foam reinforcement.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Callery Chemical Company, Callery, Pennsylvania.

FUNDS ALLOCATED:

Federal funds	$126,066
State funds	33,524
State services	8,500
Total	$168,090

COST PER CUBIC YARD: $3.36 (50,000 cubic yards).

STATUS AT LAST INSPECTION: (December 31, 1970) - The foam seal had weathered; project was not completely successful.

BACKGROUND: The refuse bank located in Iselin, Pa., is currently owned by, but has been abandoned by, the Rochester and Pittsburgh Coal Company. The material in the pile consisted primarily of breaker refuse and mine rock. Approximately 4 acres of material were burning in a slight ravine approximately 25 feet above grade at it's highest point. Water for quenching was available from a nearby stream.

METHODS: The pile was regraded and the actively burning areas were cooled and partially quenched with water. An earth-filled fire trench was placed on three sides of the bank to prevent the fire from spreading to other potentially combustible portions of the pile. Fine red dog (coal ash) and refuse was placed over the hot areas and compacted by bulldozers and sheep-foot rollers. The final configuration of the pile resembled an inverted saucer. Thirty-five thermowells were placed in the pile to a depth of 14 feet. This phase of the work required about 6 weeks.

Several 10-square-foot test patches were prepared to test the effectiveness of calcium chloride and sodium silicate as soil stabilizers. It was concluded that the use of these chemicals on the entire pile was not justified.

The polyurethane foam covering was applied during a 6-week period ending in October 1968. Two 2000-square-foot areas were foamed over two substrates - fiberglass and burlap brattice cloth. The remaining portion of the pile was compacted with a small road roller and foamed. After the foam had been applied, 65 percent of the pile was spray-coated with a tar-based coating that contained powdered aluminum. The remaining portion of the pile was sprayed with latex paint.

Temperature measurements began in September 1968, and continued on a monthly basis through September 1969.

COMMENT AND EVALUATION: Air pollutant emissions have been eliminated from this refuse bank. Hot zones in the pile will probably go out eventually, if the foam seal remains intact.

The major problem was drainage; heavy fall and winter rains and snow caused the edges of the foam to lose its seal for several feet around the perimeter of the foam cap. The contractor repaired the seal, but better drainage control will be required on future projects.

Careful site preparation is largely responsible for the success of this project. The low profile of the pile not only facilitated the application of the foam, but minimized the risk of air infiltration at the base.

A.10 ASHLEY, PENNSYLVANIA

PROJECT NUMBER: 66A-4101D.

TERM OF PROJECT: April 15, 1966 to April 14, 1967.

OBJECTIVES:

1. To determine the efficiency and economy of water immersion and compaction by heavy equipment in reducing culm-bank material below combustion temperature and quench the fire.

2. To determine if temperature of the material could be reduced below combustion temperature and to provide extinguishment by compaction through the use of heavy equipment.

3. To keep accurate records on equipment utilization for moving or processing material to permit an accurate cost determination.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Dixon Contracting Company.

FUNDS ALLOCATED:

Federal funds	$259,125
State funds	71,875
State services	14,500
Total	$354,500

COST PER CUBIC YARD: $1.14 (304,000 cubic yards).

STATUS AT LAST INSPECTION: (June 6, 1968) - The project area was partially covered by compacted refuse from project 68A-4113D, which was completed June 6, 1968. There was no evidence of heating in the pile and no visible emissions. The remaining portions of the Huber Bank are burning actively, however.

BACKGROUND: The Huber Bank complex, the largest burning coal-refuse bank in the anthracite region of Pennsylvania, has been actively burning since 1955 and is the source of much of the air pollution that periodically affects the towns of Ashley and Wilkes-Barre. Concurrent with this project, a contract from the Economic Development Administration, Department of Commerce, was applied in an effort to reduce smoke and dust during the excavation and quenching phase with a fog nozzle on a "water cannon" or "monitor." The fog nozzle materially reduced the emission of smoke and dust, and the direct stream from the water cannon effectively excavated unconsolidated bank material. This technique has been used in subsequent projects, including project 68A-4113D, as the major method of excavation. The Pennsylvania Department of Health, Division of Air Pollution, made air-quality measurements in the town of Ashley and in the vicinity of the bank during May and June 1966 and from December 1966 through February 1967. Sulfur dioxide was measured with lead-

peroxide candles and a Thomas autometer. A tape-sampler was used to measure the levels of hydrogen sulfide.

COMMENT AND EVALUATION: The project successfully extinguished 304,000 cubic yards of burning material at the Huber Bank at an average cost of $1.14 per cubic yard.

The use of fog nozzles to reduce air pollution while moving the culm was also demonstrated. The direct stream of the water monitor itself could be used to move unconsolidated culm to the quenching pools. Hydraulic methods, although not originally included in the project objectives, led to the development of the "placer mining" or "hydraulic movement" concept by the contractor and the state. Subsequent projects using this method have reduced the unit cost of extinguishing material at the Huber Bank to approximately $0.70 per cubic yard. Consequently, the latter method will most likely replace the initial project method in all future work at Huber Bank.

Ambient air monitoring showed no significant change in long-term average sulfur dioxide levels during the two periods studied. There was also no significant change in the maximum peaks recorded or in the average of all peaks for sulfur dioxide; however, the frequency of occurrence decreased slightly during the period from December 1966 to February 1967. An increase in hydrogen sulfide measured for the same period was not considered significant because concentrations during both periods were low. Although the project itself failed to substantially reduce the pollution levels, there was no pollution increase during the sampling periods, possibly as a result of eliminating two banks of the complex as pollution hazards.

A.11 GYPSY, PENNSYLVANIA

PROJECT NUMBER: 66A-4105D.

TERM OF PROJECT: September 1, 1966 to December 31, 1969.

OBJECTIVES:

1. To develop and test in the laboratory oxidation retardant formulations that could be used to extinguish fires on the surface and in the interior of coal refuse piles at a reasonable cost.

2. To test the best oxidation retardant formulation found in the laboratory on a portion of an actual coal-refuse pile.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Callery Chemical Company, Callery, Pennsylvania.

FUNDS ALLOCATED:

Federal funds	$ 96,427.04
State funds	21,642.60
State services	10,500.00
Total	$128,569.64

COST PER CUBIC YARD: Relatively high cost compared with the other methods. Cost per cubic yard is not accurately known because most of the work was performed in a laboratory.

STATUS AT LAST INSPECTION: (December 31, 1970) - This project was not successful because of a number of hot spots still present in the bank.

BACKGROUND: Four phases were originally planned for this project. During work on the project, phase 2 was dropped as being unnecessary and phase 4 (treatment of the entire coal refuse pile with an oxidant retardant formulation) was deleted after the results from phase 3 (small scale field testing of the formulations) were found to be unfavorable. Instead, two experiments, a water penetration technique involving the controlled leakage of surfactant treated water from a perforated polyethylene lined trench and a fire retardant injection method using lances to place the chemical treatment near the fire zone, were substituted for the two deleted phases.

Initially, a method had to be developed to evaluate the effectiveness of several different fire retardant chemicals in extinguishing coal-refuse-pile fires. The greatest difficulty encountered was in developing a test that would closely approximate the conditions found in a burning pile. A standard procedure was developed to evaluate the effectiveness of the following chemicals: ammonium sulfamate, ammonium polyphosphate, ammonium bromide, potassium bicarbonate, monoammonium phosphate, cobaltic oxide, methylene bromide, methyl bromide, and two proprietary chemicals, Fyrex and CWS.

The results of the testing showed ammonium sulfamate to be the most effective chemical per pound used. The testing also showed that, on a dry weight basis, ammonium polyphosphate was as effective as ammonium sulfamate when approximately 30 percent more ammonium polyphosphate than ammonium sulfamate was used. Although ammonium polyphosphate was less expensive than ammonium sulfamate, ammonium sulfamate was used in a field test at a burning refuse pile near Gypsy, Pa., on the property of the Trojan Coal and Petroleum Corporation.

METHOD: Three test areas, each 100 feet by 100 feet, were laid out on the pile and 18 thermowells were driven into the test sites. Temperature readings were recorded prior to treatment, and periodically thereafter. Sprinklers were used to distribute the chemical solutions over the test areas. Test area 1 was treated with water containing the surfactant, area 2 was treated with a solution of ammonium sulfamate and surfactant, and area 3 was left untreated as a control. The field work was initiated in February 1967 and completed in November 1969.

For the first additional experiment, a trench was dug and two perforated polyethylene-lined troughs were placed side-by-side in it. Between the two troughs, five thermowells were placed. The polyethylene liner was perforated with holes 1/32-inch in diameter that allowed the water level in the trough to drop approximately 1 inch per hour. The water used in this experiment contained only a surfactant. This experiment resulted in a definite cooling trend in the pile below it.

In the second experiment, 16 injection wands were driven into the refuse pile. The first four wands were used for injection of an ammonia-water-surfactant mixture, the next four were control wands not used for injection and the last eight wands were used to inject ammonium polyphosphate, water, and surfactant.

COMMENT AND EVALUATION: This project involved more laboratory work than any of the other demonstration projects. The laboratory work established that ammonium sulfamate and ammonium polyphosphate were the most effective chemicals tested, although it is possible that the testing method used may not have been a good representation of conditions found in a burning coal-refuse pile. This note of skepticism was generated because of the conflicting results obtained from the laboratory and field testing. In the field test, plain water cooled the pile just as much as, or possibly more than, the ammonium sulfamate-water mix. In the injection experiment, the ammonia, water, and surfactant mixture cooled the pile more than the application of nothing at all, but the pile where nothing at all was applied cooled more than where the ammonium polyphosphate, water, and surfactant mix was applied. One possible explanation is that temperature measurements were taken for too short a period (about 6 weeks) after application of the formulation to permit definite trends to be established.

Another consideration in the test involving ammonium sulfamate is that the concentrations of the chemical that were tried in the laboratory were 4.8 percent of the total sample tested; the field test was limited by economics to 1 percent by weight in 200,000 gallons of water, or approximately 16,700 pounds of sulfamate. The test area contained approximately 32,000,000 pounds of refuse. A uniform distribution of sulfamate would only result in a concentration of 0.052 percent, which is 100 times smaller than the concentration indicated by laboratory testing.

If 4.8 percent by weight of sulfamate were used to treat the 32,000,000 pounds of refuse, approximately 1,613,000 pounds of sulfamate would be needed. The Gallery Chemical Company paid $0.20 per pound for the 20,000 pounds of sulfamate purchased for the project. Based on this price, the necessary 1,613,000 pounds would cost $322,600.

The cost of the chemicals needed to treat a cubic yard of refuse pile would be approximately $20 as compared to a total average cost for seven other "good" coal refuse pile extinguishment projects of $0.96 per cubic yard.

A.12 WHITE STATION, PENNSYLVANIA

PROJECT NUMBER: 66A-4106D.

TERM OF PROJECT: August 1, 1966 to December 30, 1968.

OBJECTIVES:

1. To determine whether the remote application of water by means of high-pressure spray nozzles could economically cool and quench burning culm banks.

2. To determine whether the quenched material could be permanently extinguished by mixing the cooled material with noncombustible red dog.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Adrian D. Davis, Homer City, Pennsylvania.

FUNDS ALLOCATED:

Federal funds	$49,762.50
State funds	8,587.50
State services	8,000.00
Total	$66,350.00

COST PER CUBIC YARD: $0.66 (100,485 cubic yards).

STATUS AT LAST INSPECTION: (December 31, 1971) - The piles were effectively extinguished with no visible emissions and no indication of further heating. Project completely successful.

BACKGROUND: The refuse bank at White Station had burned for several years after the mining operation of the Westmoreland Mining Company stopped in the late 1950's. The villages of White Station and Moween experienced increasing episodes of serious air pollution from the gaseous emissions from these banks. The site was chosen for the demonstration because it offered not only an unlimited water supply from the Conemaugh River, but also adequate space to permit heavy equipment to excavate the burning refuse and to repile it in compacted layers without transporting the extinguished material a great distance.

METHOD: The noncombustible red dog was scraped off the previously burned portions of the pile by bulldozer. Water sprays were used to wet-down and cool the hot, burning sections of each pile. The wet material was subsequently removed by bulldozer and repiled in alternate layers with red dog. Each layer was compacted during this process and the resultant pile was shaped to eliminate high walls that might permit air to intrude into the pile.

The work was accomplished over a 33-week period, during which time 100,485 cubic yards of material were processed. The combined piles were spread over approximately 19 acres.

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COMMENT AND EVALUATION: This project successfully extinguished the burning banks at White Station. The cost appears to be quite reasonable considering that the contractor had no previous experience with such work.

The major value of this project is that it demonstrated conclusively that, if ample water and space are available, many of the burning banks in western Pennsylvania can be extinguished by competent earth-moving contractors using standard equipment and commercially available pumps equipped with an easily fabricated sprinkler system. In the future, competitive bidding will, no doubt, reduce the unit cost below the reported values.

A.13 SCRANTON, PENNSYLVANIA

PROJECT NUMBER: 66A-4108D.

TERM OF PROJECT: August 1, 1966 to June 30, 1968.

OBJECTIVES:

1. To determine whether the use of explosives to loosen the heavy clinker in burning culm banks could successfully open the underlying hot areas to solid streams of water.

2. To determine whether the heavy application of water, with rapid heat exchange at the seat of the fire, would reduce the temperature of the mass below combustion levels and permanently extinguish the fire.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Scranton Excavating Company.

FUNDS ALLOCATED:

Federal funds	$27,073.00
State funds	4,024.48
State services	5,000.00
Total	$36,097.48

COST PER CUBIC YARD: $2.19 (16,500 cubic yards).

STATUS AT LAST INSPECTION: (December 31, 1970) - The major portion of the pile was burning; however, project was completely successful.

METHOD: Site preparation required the installation of a pump and a 14-inch-diameter water pipeline, and the drilling of five 6-inch-diameter horizontal holes. The holes varied in depth from 34 to 47 feet. Internal temperature measurements were taken to ensure safe conditions for loading explosives. After the holes were cooled with water, explosive charges were inserted and detonated. The rubble was subsequently doused with water at the rate of 4,000 gal/min, for 8 hours a day, over a 5-day period. The cooled rubble was then removed to an adjacent disposal area.

COMMENT AND EVALUATION: The project successfully demonstrated that explosives can be used to break up monolithic surface clinkers in culm banks and permit subsequent water extinguishment. The economics of this project were not particularly attractive ($2.19 per cubic yard of material extinguished) because of high nonrecurring costs and site-preparation expenses. A later $50,000 project funded entirely by the State of Pennsylvania extinguished 125,000 cubic yards of material at a unit cost of $0.40 per cubic yard. The two projects together had a cost per cubic yard of approximately $0.61, a more valid figure to use for estimating purposes.

Assuming that the original survey of this bank was fairly accurate and that the bank contains approximately 2,746,000 cubic yards of material, an additional expenditure

of approximately $1,100,000 would be required to completely extinguish this bank at a unit cost of $0.40 per cubic yard.

The air pollution measurements show a local increase in particulate, hydrogen sulfide, and sulfur dioxide levels shortly after the explosions and during the "wet down" period. The State Department of Health, therefore, believes that this method of extinguishing culm-bank fires may not be appropriate for use in densely populated areas. The Department of Mines and Mineral Industries, however, believes that these adverse air quality conditions were a temporary, minimal hazard in view of the overall success of the project.

This method will probably not be widely used outside the anthracite region of Pennsylvania because of its requirements for an unlimited water supply and for ample space to dispose of quenched material. Many of these banks are in late stages of burning, so that the surface of the pile is covered with red dog and consolidated clinker to a depth of 10 to 20 feet or more. In order to get at the fire in these banks, explosives will have to be used. It is believed, however, that after the consolidated material has been removed there are more effective means of extinguishing and moving the remaining material. These include the water-monitor-lagoon method and the water-monitor-dozer method that was demonstrated in project 66A-4101D (appendix A.10).

A.14 NORTH SCRANTON, PENNSYLVANIA

PROJECT NUMBER: 67A-4109D.

TERM OF PROJECT: January 1, 1967 to June 1, 1968.

OBJECTIVES:

1. To determine whether the remote application of water by means of high-pressure hydraulic guns could quench burning culm material efficiently and economically.

2. To determine whether the quenched material could be moved and compacted.

GRANTEE: The Commonwealth of Pennsylvania, Department of Mines and Mineral Industries.

CONTRACTOR: Dixon Contracting Company.

FUNDS ALLOCATED:

Federal funds	$240,000
State funds	200,000
State services	8,500
Total	$448,500

COST PER CUBIC YARD: $0.76 (586,666 cubic yards).

STATUS AT LAST INSPECTION: (December 31, 1970) - Project was a complete success.

BACKGROUND: The bank is located near the former Marvin Colliery of the Glen Alden-Hudson Coal Company at Dixon City, Pa. The bank is divided into two separate piles estimated to contain 3,760,000 and 4,300,000 tons of refuse, respectively. When this project began, approximately 50 percent of each pile was burning. These banks have been on fire for at least 10 years. The smaller bank was selected for the demonstration project because of its proximity to a section of highway where the smoke and fumes often created a serious traffic hazard.

METHOD: A depression between the banks was deepened to form a basin for catching the run-off water, and a 165-foot well was drilled to tap a pool of mine water. A 6,000 gal/min pump was installed and 1,500 feet of pipe were utilized to transport the water to the water monitors. A direct stream of water from the monitors was played on the pile, working from the top downward to the quenching pool at the base of the bank. When the dislodged hot material had been quenched, it was removed from the pool by the dragline and dumped a short distance from the pile. A bulldozer then spread the material in 1-foot layers to allow it to cool. Landscrapers removed the cooled material to the disposal area, where a second bulldozer spread the quenched culm and compacted it. During the 142-day project, 586,666 cubic yards of material were extinguished.

COMMENT AND EVALUATION: The project effectively extinguished the burning material, proved that the use of earth-moving equipment was feasible, and showed a $0.76 per cubic yard cost that was significantly lower than previous mechanical-hydraulic methods.

Subsequent state projects using this method and costing $1,000,000 have practically leveled the pile and extinguished all fire in the smaller portion of the Marvin Bank. Because the cost includes approximately $122,000 for installation, such as drilling a well, preparing the site, and installing the deep-well pump, future projects at this site should have a unit cost of approximately $0.54 per cubic yard of material treated. Pennsylvania mine officials believe that these unit costs could be further reduced, if an additional dragline were used on subsequent projects.

The use of a fog nozzle on one of the water monitors minimized dust and fumes in the working area. The method also practically eliminated the need for protective breathing apparatus for workmen.

This method will be followed in most culm-bank-extinguishment projects in the anthracite region, where the terrain and water supplies permit.

A.15 ASHLEY, PENNSYLVANIA

PROJECT NUMBER: 68A-4113D.

TERM OF PROJECT: March 1, 1968 to September 30, 1968.

OBJECTIVE:

To determine the relative effectiveness of two methods of extinguishing culm-bank fires. Method 1 used a water monitor, dragline, bulldozer, and landscraper to remove, quench, transport, and compact the burning material. Method 2 repeated method 1, but also used the water monitor to cool the bank material, remove it and transport it to an area where it was compacted in alternate layers with material quenched by method 1. The methods were operated concurrently upon adjacent portions of the bank, but the disposal areas were separated.

GRANTEE: Commonwealth Development Association of Pennsylvania.

CONTRACTOR: Dixon Contracting Company.

FUNDS ALLOCATED:

Federal funds	$281,735.65
Non-Federal funds	100,000.00
Total	$381,735.65

COST PER CUBIC YARD:

Method 1 - $0.71 (261,771 cubic yards)
Method 2 - $1.04 (189,500 cubic yards)
Project Total 451,271 cubic yards

STATUS AT LAST INSPECTION: (July 23, 1969) - No evidence of heating was found in either refuse-disposal area.

BACKGROUND: The Huber Bank complex, the largest burning coal-refuse bank in the anthracite region of Pennsylvania, has been actively burning since 1955 and is the source of much of the air pollution that periodically affects the towns of Ashley and Wilkes-Barre. This project and the other projects conducted at this site were undertaken in response to citizen's complaints and to state and Federal concern over the air pollution problem. The methods demonstrated had been successfully applied elsewhere in Pennsylvania, but not in combination or on the scale of this project.

METHOD: In method 1, a water monitor was used to excavate the burning material from the highwall of the bank into a water-filled lagoon that was formed at the base of the highwall. The wet, quenched culm was removed by a dragline to a landscraper, transported to the disposal area, dumped, and smoothed and compacted by a bulldozer. Method 2 essentially duplicated method 1, but the water monitor alternated between excavating the culm and wetting down the top portion of the bank. This latter material was pushed down an inclined portion of the bank to a landscraper that moved it to a separate disposal area, where it was deposited in alternate layers with the monitor-quenched material from method 2.

Method 2 required two 19-cubic-yard landscrapers; method 1 required only one. With these exceptions, the equipment used in each method was identical and consisted of one 7-cubic-yard dragline, four bulldozers, and a water monitor. The hydraulic system consisted of an existing 12,000,000 gallon collecting reservoir, approximately 2,500 feet of 10- to 8-inch steel and aluminum pipe. An electrically powered Barret and Haentjens horizontal pump rated at 4,000 gal/min at 150 psig served the piping system that supplied both water monitors.

At the completion of the active extinguishment work, thermowells were placed in 18 open-cased bore holes that were strategically located throughout both storage areas. All of these thermowells registered only ambient temperatures since the completion of the project.

COMMENT AND EVALUATION: This was the largest and most effective extinguishment project that had been undertaken at Huber. Before its completion, various efforts to extinguish the burning refuse in this area of the Huber Bank had extinguished approximately 610,000 cubic yards at a total cost of $697,500.00, a unit cost of $1.14 per cubic yard. Together, the project methods had an average unit cost of $0.845 per cubic yard; method 1 had a unit cost of approximately $0.71 per cubic yard. For method 2 the higher cost of $1.04 per cubic yard was at least partially dictated by the shape of the pile and the longer distances that the quenched material had to be moved to reach the disposal area.

The Pennsylvania Department of Mines and Mineral Industries has conducted several large extinguishment projects using method 1 at the Marvin and Huber Banks since the completion of this project. The State of Pennsylvania expects to use this method whenever available water and terrain permit. Pennsylvania is expected to continue using bond-issue funds, augmented with Federal funds, for projects to extinguish these fires. In a 1968 survey, the U.S. Bureau of Mines estimated that the 27 burning banks in the anthracite region contained approximately 54,500,000 cubic yards of refuse. Assuming that half of this volume must be processed in order to extinguish these fires, it is estimated that the total cost of such an effort will approximate $20 to $25 million.